

HAEMATOLOGY OF THE PRIMATES

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While occasional references may be found regarding the red cell counts and the differential counts of certain primates, these are usually secondary matters arising in connection with some research problem. Aside from the work of Gulliver (1875), which concerns itself with the red cell sizes alone, there is no single investigation dealing primarily with the haematology of the primates. The present study has been undertaken with a view to fulfilling the need for this particular investigation.

The blood of the monkeys is best obtained from a marginal ear vein. The ear is first shaved and rubbed with ether or benzene; a prominent vein near the margin of the ear is then opened with a single cut with a razor blade. Much of the difficulty which may be experienced in controlling adult specimens of the larger primates may be avoided by using young animals, but the difficulty is not as a rule great if the animal is held by a keeper with whom it is familiar.

With the exception of the blood of the spider monkeys, the dilutions for the red blood cell count, white blood cell count, haemoglobin determination, and occasionally for the suspensions for haemolysis, were made from fresh unoxalated blood. The smears for the differential counts and polynuclear counts were obtained at the same time. The blood of the spider monkeys was collected into oxalate in the usual proportions. Owing to the difficulty which we have experienced in obtaining more than quite small quantities of blood from many of the monkeys, a modification has been introduced in the method of preparing the films of cells for measurement. A small volume of blood is drawn into a capillary pipette, which is then sealed at both ends. When the preparation of red cells is made for photography, the seals are removed and the contents of the tube, consisting of serum and clot, expelled on to the surface of a slide. The clot is removed with a pair of fine forceps, and the remaining serum covered with a coverslip. The

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serum always contains a considerable number of cells, which can be photographed and measured in the usual manner. Under these conditions the cells are measured in serum instead of in oxalated plasma, but this does not affect their mean diameter.

Except where otherwise stated, the technique employed is identical with that described in the first paper of this series (Haematology of the Camelidae). It should also be mentioned that the general morphology of the leucocytes of the primates examined in this investigation is so much like that of the leucocytes of man that differences alone are described.

I. Gorilla gorilla

a—The red cells are typical biconcave discs similar to the red cells of man. Their mean diameter, however, is slightly smaller. Cells in plasma have a mean diameter of $7.7\ \mu$, while cells in dried films have a diameter of $7.3\ \mu$.

b—The average haemoglobin percentage is 83 per cent.

c—Red cell count per cubic millimetre, 6,250,000.

d—White cell count per cubic millimetre, 6,800.

e—The morphology of the cells presents several points of interest.

1—The polymorphonuclear neutrophils (P. M. N.) are circular in outline and range in size from 9 to $12\ \mu$. There appears to be a predominance of bilobed cells. The cytoplasm, granules, and nucleus are typical.

2—The polymorphonuclear eosinophils (P. M. E.) measure approximately $11\ \mu$. The deep red granules are evenly distributed throughout the light blue cytoplasm. The nucleus stains less intensely than that of the neutrophils.

3—The polymorphonuclear basophils (P. M. B.) are circular and measure about $10\ \mu$. The nucleus is obscured by the coarse basophilic granules. The cell has the appearance of a compact mass of chromatin with minute chromophobic areas.

4—The lymphocytes (L) are the smallest of the white cells, and measure only $8\ \mu$. The nucleus is irregular and practically fills the cell.

5—The large mononuclears (L. M.) are variable in outline from perfect circles to irregular ovals. They measure about $16\ \mu$. The eccentrically placed nucleus stains a deep blue. There are a very few coarse azure granules scattered throughout the cytoplasm.

6—The transitional leucocytes (T) closely resemble the class I polymorphs in size and shape. The granules in the cytoplasm are coarser and are concentrated about the nucleus.

f—The differential count is as follows:

P. M. N.	63	L.	23
P. M. E.	5	L. M.	4
P. M. B.	3	T.	2

g—The polynuclear count is similar to that of man, and is as follows:
17:28:39:14:2.

II. *Pan calvus* (Chimpanzee)

a—The red cell size alone is worthy of record. The cells in plasma measure 7.8 μ , while dry cells measure 7.4 μ .

b—Haemoglobin, 89 per cent.

c—Red cell count, 7,300,000.

d—White cell count, 10,400.

e—The leucocytes of this animal show no variations worthy of note, except that the lymphocytes have an extremely thin layer of light blue cytoplasm about a large irregular nucleus. Small dark granules can be seen scattered at random in the scanty cytoplasm. The measurements of the white cells are:

P. M. N.	8-10 μ .	L.	7 μ .
P. M. E.	9 μ .	L. M.	11 μ .
P. M. B.	5-10 μ .	T.	(none found)

f—The differential count is as follows:

P. M. N.	58	L.	16
P. M. E.	5	L. M.	1
P. M. B.	20	T.	—

g—The polynuclear count is 3 : 12 : 45 : 32 : 8.

h—The resistance of the red cells to haemolysins is as follows:

1—The resistance to saponin is 1.7 times that of the cells of man.

2—The resistance to taurocholate is 2.7 times that of human cells.

3—The red cells are resistant to 0.28 per cent NaCl, a resistance considerably greater than that of human erythrocytes.

III. *Pongo pygmaeus* (Orang-utan)

a—The red cells in plasma measure 7.8 μ , while dried cells measure only 7.4 μ .

b—Haemoglobin, 80 per cent.

c—Red cell count, 6,880,000.

d—White cell count 9,400.

e—The morphology of the leucocytes presents a few interesting features.

1—The polymorphs have an uneven outline which can be considered as roughly circular. They measure 10 μ in diameter. The nucleus is multi-lobed and uneven; the cytoplasm shows a variable staining reaction owing to the fact that it is studded with a mixture of eosinophile and basophile granules.

2—The eosinophiles are almost circular in outline, and measure 7 μ in diameter. The nucleus stains a light purple and is set in a poorly staining cytoplasm with coarse eosinophile granules.

3—The basophiles resemble small lymphocytes with coarse basophilic granules. The nucleus is fairly regular, but its outline is difficult to trace owing to the number of the cytoplasmic granules. The cytoplasm seen between the granules is light blue. The size varies from 5 to 8 μ .

4—The lymphocytes are about 5 μ in diameter. The time required for staining the smears of this blood is quite different from that ordinarily used. The initial staining proceeds rapidly (15 to 25 seconds), while the differentiation requires a full two minutes.

f—The differential count is:

P. M. N.	55	L.	24
P. M. E.	4	L. M.	2
P. M. B.	15	T.	—

g—The polynuclear count is 3 : 12 : 40 : 28 : 17.

IV. *Papio cynocephalus* (Yellow Baboon)

a—Red cells in plasma measure 7.7 μ , while dried cells measure 7.3 μ .

b—Haemoglobin, 87 per cent.

c—Red cell count, 6,970,000.

d—White cell count, 10,400.

e—With the exception of the size of the eosinophiles, which measure 17 μ , the white cells of this monkey show few differences from those of man. The transitional leucocytes are rather small, measuring only about 11 μ as opposed to the 20 μ measurement for the same cells in man. The sizes of the other white cells are given below:

P. M. N.	12 μ	L.	8 μ
P. M. B.	10 μ	L. M.	19 μ

f—The differential count is: —

P. M. N.	65	L	29
P. M. E.	2	L. M.	2
P. M. B.	1	T.	1

g—The polynuclear count is 10 : 25 : 40 : 20 : 5.

h—The resistance to saponin is 0.57 times that of human cells, and the resistance to taurocholate 0.42 times as great. The cells resist 0.18 per cent NaCl; this is a very great resistance indeed.

V. *Lasiopyga griseoviridis* (Green Monkey)

a—Cells in plasma measure 7.8 μ , while dried cells measure 7.4 μ .

b—Haemoglobin, 87 per cent.

c—Red cell count, 6,400,000.

d—White cell count, 12,600.

e—The staining properties and morphology of the cells require no description. The cells sizes are:—

P. M. N.	10 μ	L.	8 μ
P. M. E.	7 μ	L. M.	12 μ
P. M. B.	10 μ	T.	—

f—The differential count is:—

P. M. N.	58	L	31
P. M. E.	7	L. M.	3
P. M. B.	1	T.	none

g—The polynuclear count is 8 : 20 : 38 : 22 : 12.

h—The resistance to saponin is 0.9 times that of the cells of man; to taurocholate the resistance is 0.40. The cells are less resistant to NaCl than are the cells of man, haemolysing at 0.43 per cent.

VII. *Magus maurus* (Celebes Macaque)

a—Red cells in serum, 7.9 μ ; in the dried state, 7.2 μ .

b—Haemoglobin, 88 per cent.

c—Red cell count, 5,000,000.

d—White cell count, 7,600.

e—The transitional leucocytes contain a mixture of basophilic and eosinophilic granules in addition to the typical lilac colored granules. Otherwise there is no noteworthy difference from the cells of man. The cell sizes are:—

P. M. N.	10 μ	L.	23 μ
P. M. E.	9 μ	L. M.	14 μ
P. M. B.	8 μ	T.	19 μ

f—The differential count is:—

P. M. N.	69	L.	23
P. M. E.	2	L. M.	1
P. M. B.	4	T.	1

g—The polynuclear count is 32 : 32 : 31 : 5 : 0.

h—The resistance to saponin is 1.55 times as great as in man, while the resistance to taurocholate is 0.55 times as great. The cells resist 0.22 per cent NaCl.

VI. *Pithecus rhesus* (Rhesus Monkey)

a—Red cells in plasma measure 8.0 μ , while dried cells measure 7.3 μ .

b—Haemoglobin 77 per cent.

c—Red cell count, 5,000,000.

d—White cell count, 10,400.

e—The blood elements of this form are decidedly chromophilic, for they stain easily and differentiate rapidly. The lymphocytes especially show a marked differential staining. Their cytoplasm stains a beautiful blue, while the azure granules stand out in bold relief. The cell sizes are:—

P. M. N.	5 μ	L.	5 μ
P. M. E.	6 μ	L. M.	12 μ
P. M. B.	7 μ	T.	—

These cells are all rather small in size, the largest being no bigger than a polymorph of human blood.

f—The differential count is:—

P. M. N.	73	L	18
P. M. E.	3	L. M.	2
P. M. B.	1	T.	none

g—The polynuclear count is 12 : 32 : 40 : 14 : 2.

h—The resistance to saponin is 0.73 times that of human cells, while to taurocholate it is approximately the same. The cells resist 0.27 per cent NaCl, and are therefore more resistant than the cells of man.

VIII. *Pithecus irus* (Common Macaque)

a—Red cells in serum, 8.0 μ ; in dried films, 7.1 μ .

b—Haemoglobin, 90 per cent.

c—Red cell count, 6,432,000.

d—White cell count, 7,200.

e—The polymorphs are typical, and measure $10\ \mu$ in diameter. The eosinophiles occur in quite large numbers, and measure $8\ \mu$ in diameter; their granules are large and uniform, and stain an intense red. The nucleus is less lobated than usual. The basophiles are also numerous, and measure $7\text{--}12\ \mu$. The lymphocytes measure $10\ \mu$, the monónuclears $15\ \mu$, and the transitionals $11\ \mu$.

f—The differential count is:—

P. M. N.	37	L.	18
P. M. E.	19	L. M.	1
P. M. B.	24	T.	1

g—The polynuclear count is $18:37:39:6:0$.

h—The resistance of the red cells is given by the following figures: saponin, 1.0, taurocholate, 0.49, hypotonic saline, 0.16 per cent NaCl. This latter is the greatest resistance yet recorded.

IX. *Cebus fatuellus* (Sapajou)

a—Red cells in plasma, $7.8\ \mu$; in dried films, $6.8\ \mu$.

b—Haemoglobin, 90 per cent.

c—Red cell count, 5,100,000.

d—White cell count, 10,400.

e—The polymorphs are difficult to stain properly, and the nucleus is obscured by the eosinophilic and basophilic granules which fill the cytoplasm. There are some neutrophile granules present. The size of these cells is $13\ \mu$. The lymphocytes are peculiar in that they contain an irregular nucleus with slightly scalloped margins. The cell sizes are:—

P. M. N.	$13\ \mu$	L.	$8\ \mu$
P. M. E.	$10\ \mu$	L. M.	$11\ \mu$
P. M. B.	$7\ \mu$	T.	$11\ \mu$

f—The differential count is:—

P. M. N.	68	L.	21
P. M. E.	5	L. M.	2
P. M. B.	3	T.	1

g—The polynuclear count is $10:22:42:18:8$.

h—The resistance to haemolysins is shown by the following figures: saponin, 1.42, taurocholate, 1.12, hypotonic saline, 0.38 per cent NaCl.

X. *Ateles ater* (Black Spider Monkey)

a—Red cells in plasma, $9.1\ \mu$; in dried films, $7.7\ \mu$.

b—Haemoglobin, 76 per cent.

c—Red cell count, 5,760,000.

d—White cell count, 10,000.

e—The eosinophiles are peculiar in that areas of the cytoplasm do not contain granules of any kind. The large bright red granules are concentrated on one side of the nucleus, leaving the remaining part of the clear light blue

cytoplasm devoid of granules. No large mononuclears or transitional cells appear to be present. The sizes of the cells are:—

P. M. N.	13-17 μ	L.	10 μ
P. M. E.	12 μ	L. M.	—
P. M. B.	8 μ	T.	—

f—Differential count:—

P. M. N.	69	L.	18
P. M. E.	12	L. M.	none
P. M. B.	1	T.	none

g—Polynuclear count:—3 : 6 : 5 : 10 : 10 : 10 : 14 : 42. This is a most remarkable count, for not only are there eight classes, but as many as 42 cells show eight nuclear lobes.

h—Resistance to haemolysins:—saponin, 1.24, taurocholate, 1.63, hypotonic saline, 0.28 per cent NaCl.

XI. *Ateles geoffroyi* (Gray Spider Monkey)

a—Red cells in plasma, 8.8 μ ; in dried films, 7.9 μ .

b—Haemoglobin, 80 per cent.

c—Red cell count, 3,840,000.

d—White cell count, 7,000.

e—The polymorphs are approximately 10 μ in diameter, and contain extremely lightly staining cytoplasm filled with fine neutrophile granules. The basophiles appear to be composed almost entirely of nuclear material, only a few basophilic granules being resolvable at the edge of the cell. The lymphocytes also have very little cytoplasm, and contain a few azure granules. The large mononuclears have a clear sky blue cytoplasm which contains no granules at all. The cell sizes are:—

P. M. N.	10 μ	L.	8 μ
P. M. E.	11 μ	L. M.	13 μ
P. M. B.	6-8 μ	T.	—

f—Differential count:—

P. M. N.	73	L.	15
P. M. E.	8	L. M.	1
P. M. B.	3	T.	none

g—Polynuclear count:—8 : 18 : 21 : 29 : 19 : 4 : 1. Like the count of *Ateles ater*, the count is very right handed.

h—Resistance to haemolysins:—saponin, 1.28, taurocholate, 1.46, hypotonic saline 0.28 per cent NaCl.

XII. *Saimiri sciureus* (Squirrel Monkey)

a—Red cells in serum, 6.4 μ ; in dried films, 6.1 μ .

b—Haemoglobin, 84 per cent.

c—Red cell count, 7,416,000.

d—White cell count, 11,000.

e—The lymphocytes can properly be divided into small and large, for they show a wide variation in size (5-14 μ). The other cells are typical. The sizes are:—

P. M. N.	10 μ	L.	5-14 μ
P. M. E.	8 μ	L. M.	12 μ
P. M. B.	8 μ	T.	—

f—Differential count:—

P. M. N.	65	L.	26
P. M. E.	6	L. M.	1
P. M. B.	2	T.	none

g—Polynuclear count:—8 : 15 : 30 : 22 : 15 : 10.

h—Resistance to haemolysins:—saponin, 0.90, taurocholate, 0.95, hypotonic saline, 0.27 per cent NaCl.

XIII. *Aotus trivirgatus* (Owl Monkey)

a—Red cells in serum, 7.1 μ ; in dried films, 6.7 μ .

b—Haemoglobin, 71 per cent.

c—Red cell count, 4,664,000.

d—White cell count, 8,200.

e—The films are exceedingly difficult to stain, owing to the serum taking on a grayish-blue color which obscures the cell outline. Direct fixation with methyl alcohol before staining seems to help, but no satisfactory technique has been developed for dealing with the blood films of this animal. Except that there are no large mononuclears or transitional cells, all the leucocytes observed were found to be typical. The cells sizes are:—

P. M. N.	7 μ	P. M. B.	8 μ
P. M. E.	10 μ	L.	9-10 μ

f—Differential count:—

P. M. N.	79	P. M. B.	1
P. M. E.	8	L.	12

g—Polynuclear count:—6 : 20 : 34 : 16 : 4.

XIV. *Callithrix jacchus* (Marmoset)

a—Red cells in serum, 7.7 μ ; in dried films, 7.0 μ .

b—Haemoglobin, 67 per cent.

c—Red cell count, 6,624,000.

d—White cell count, 7,800.

e—The mononuclears are atypical in that the cytoplasm stains a light blue and is filled with fine purple granules which are evenly distributed. The nucleus is approximately central. The cell sizes are:—

P. M. N.	10-11 μ	L.	5-9 μ
P. M. E.	11 μ	L. M.	16 μ
P. M. B.	8 μ	T.	—

f—Differential count:—

P. M. N.	72	L.	19
P. M. E.	2	L. M.	3
P. M. B.	4	T.	none

g—Polynuclear count:—35 : 32 : 28 : 5 : 0. This count is a little left handed.

h—Resistance to haemolysins:—saponin, 0.57, taurocholate, 0.71, hypotonic saline, 0.40 per cent NaCl.

XV. *Lemur catta* (Ring-tailed Lemur)

a—Red cells in plasma, 6.8μ ; in dried films, 6.3μ .

b—Haemoglobin, 87 per cent.

c—Red cell count, 7,936,000.

d—White cell count, 16,400.

e—The polymorphs are typical except that they contain some rather coarse neutrophile granules. The eosinophiles contain peculiar red granules, characterized by their hyaline appearance. The lymphocytes contain an exceedingly small amount of cytoplasm. The sizes are:—

P. M. N.	10μ	L.	$6-8 \mu$
P. M. E.	10μ	L. M.	12μ
P. M. B.	9μ	T.	13μ

f—Differential count:—

P. M. N.	66	L.	23
P. M. E.	7	L. M.	1
P. M. B.	2	T.	1

g—Polynuclear count:—5 : 25 : 38 : 25 : 7.

h—Resistance to haemolysins:—saponin, 0.64, taurocholate, 1.0, hypotonic saline 0.42. This latter figure is greater than that for the cells of man.

XVI. *Lemur mongos* (Brown Lemur)

a—Red cells in plasma, 6.7μ ; in dried films, 6.3μ .

b—Haemoglobin, 75 per cent.

c—Red cell count, 10,304,000.

d—White cell count, 15,400.

e—No transitional or mononuclear cells could be found. The eosinophiles contain only a few red staining granules. The basophiles also contain few granules. The sizes are:—

P. M. N.	10μ	P. M. B.	$6-8 \mu$
P. M. E.	11μ	L.	$9-12 \mu$

f—Differential counts:—

P. M. N.	69	L.	27
P. M. E.	1	L. M.	none
P. M. B.	3	T.	none

g—Polynuclear count:—5 : 18 : 40 : 25 : 10 : 2.

Atypical leucocytes

While examining the stained smears of the blood of the sapajou, gorilla, and squirrel monkey, a large polymorphonuclear leucocyte was encountered, which measured from $18-23 \mu$ in diameter. The nucleus is typically polymorphic, stains a deep purple, and has at least four lobes. The cytoplasm is clear, stains light pink, and contains no granules. It occurs approximately once in every 200 cells.

SUMMARY

Except for small differences of size the red cells of the Primates resemble those of man. The largest cells are those of the spider monkeys while the smallest are those of the lemurs. The red cell counts vary from 5,000,000 to 7,000,000 and the haemoglobin content from 75 to 90 per cent. The erythrocytes offer considerable variations in their resistance to haemolysis by simple haemolysins, but are in general considerably more resistant to hypotonic saline haemolysis than are human cells. The morphology of the white cells is very similar to that found in man, minor differences only being found, and the differential counts present no unusual features. The total white cell count varies from 7,000 to 16,000. For most genera of monkeys the polynuclear count is more right-handed than the count for man and in the case of *Ateles ater* as many as 40 per cent of the polymorphs may be cells containing 7 nuclear lobes.

A fuller account of the haematology of the Primates will be found in the Quarterly Journal of Experimental Physiology, vol. xix.